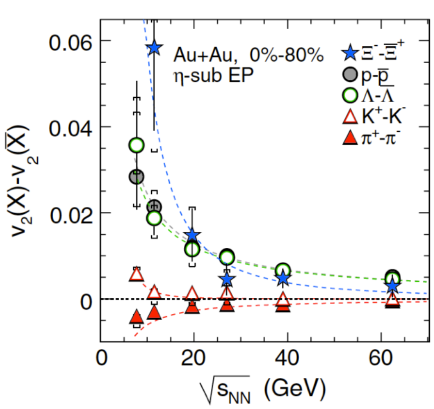
Nuclear Science Division Newsletter 2013/4

STAR observes energy-dependent particle-antiparticle asymmetry in elliptic flow

The Beam Energy Scan at *RHIC* seeks to explore the properties of strongly interacting matter and elucidate its thermodynamic phase structure, in particular whether there exists a critical endpoint. Towards this goal, analyzing data taken in 2010 and 2011, the *STAR* collaboration, in which NSD's RNC group plays a major role, has recently extracted the elliptic flow coefficient for identified hadrons at mid-rapidity in gold-gold collisions at energies of $\sqrt{s_{NN}}$ = 7.7, 11.5, 19.6, 27.0, and 62.4 GeV.

As was previously found, the magnitude of v_2 measured at high collision energy is proportional to the number of quark or antiquark constituents in the observed hadron (two in mesons, three in baryons). This so-called *constituent quark scaling* supports the formation of a deconfined quark-gluon plasma. As the beam energy is lowered, the simple scaling behavior breaks down to an ever increasing degree. In particular, a significant difference develops between the flow of particles and that of the corresponding antiparticles, as shown in the figure below. Nevertheless, for the particle species (baryons and positive pions and kaons), the constituent quark scaling remains valid to a level of 10%, whereas the difference between the v_2 values for antiparticle baryons and mesons exhibit a steady increase at decreasing $\sqrt{s_{NN}}$. This observation, along with other interesting observations such as the reaction-plane dependence of two-particle correlations and energy dependence of directed flow, indicates that as $\sqrt{s_{NN}}$ is decreased, hadronic interactions grow dominant. The second stage of the RHIC beam energy scan (BES II) is planned to occur during 2018-19; the addition of electron beam cooling as well as upgrades of the inner TPC and the BBC detector will make it possible to take data with higher statistics, and to go to lower energies, which will help to achieve a better understanding of the QCD phase structure.



The measured difference in v_2 between various particles and anti-particles (indicated) as a function of $\sqrt{s_{NN}}$ for central Au+Au collisions, together with power-law fits (dashed curves). The error bars depict the combined statistical and systematic errors. The difference in the v_2 values for particles and anti-particles increases with decreasing beam energy. The energy dependence is similar for all baryons in shape and magnitude but very different from the meson results.

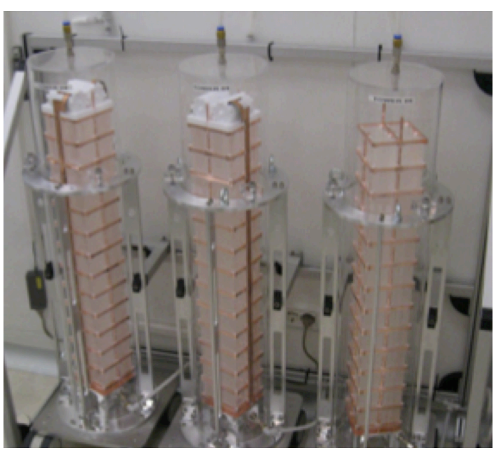
This first observation of a beam-energy dependent difference in the elliptic flow of particles and the corresponding anti-particles was recently published as Physical Review Letters **110**, 142310 (2013) and it has already given rise to six theory papers offering a variety of interpretations of the data.

CUORE tower assembly progresses well

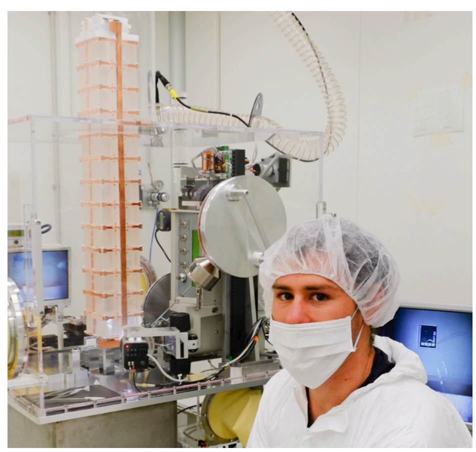
A longstanding fundamental issue in elementary particle physics is whether the neutrino differs from its antiparticle, as is the case for all other known fermions, or is identical to it, as was suggested by Ettore Majorana in 1937. The NSD is participating in a major international effort to settle this experimentally.

CUORE (Cryogenic Underground Observatory for Rare Events) is an Italy-US-China ton-scale bolometric detector that is currently under construction at the Instituto Nazionale di Fisica Nucleare Laboratori Nationali del Gran Sasso (INFN-LNGS) in Italy. The primary purpose of CUORE is to search for the neutrino-less double β decay ($0\nu\beta\beta$) of ^{130}Te which, if observed, would establish the Majorana nature of the neutrino and, in addition, would provide information on the absolute mass scale of the neutrino. The *CUORE* detector consists of 988 $5\times5\times5$ cm natural tellurium-oxide crystals mounted in 19 towers with a total mass of about 1 ton. Each crystal is instrumented with a Neutron Transmutation Doped (NTD) thermistor to measure the small temperature rise that would result from a $0\nu\beta\beta$ event. The NTD thermistors are produced at LBNL.

The tower assembly procedure involves gluing the NTD thermistors and heaters (for stabilization) to the individual crystals, loading the crystals into the tower, and then wire bonding the electrical connections. In order to prevent the radioactive contaminants, all of the tower assembly work is performed in a sealed glove box located in a clean room. The tower assembly, which began in Spring 2013, has now passed the halfway point: the assembly of 8 towers have been completed and an additional 5 towers are partially completed. Several challenges were encountered during the tower assembly, the most serious being the high failure rate of wire bonds on a batch of NTD thermistors. After some investigation, this problem was solved by improved cleaning of the NTD thermistors and by adjusting the parameters of the wire bonding machine. The CUORE tower assembly is scheduled to be completed on time in Spring 2014.



The fully assembled CUORE towers stored in a clean and dry nitrogen atmosphere.



NSD undergraduate research assistant David Miller after completing the wire bonding on the first tower.

The LBNL Institute for Nuclear and Particle Astrophysics celebrates 20th anniversary

> *"Because astrophysical events, including the very origin of the Universe, are governed by the physics of nuclei and particles, cooperative research in these disciplines is especially appropriate and should be encouraged. … It is intended for the Institute to bring together experimenters and theorists with common scientific goals and shared techniques that transcend divisional boundaries to create a vital astrophysics community at LBL."*

These words, expressed at the organizational meeting for the Institute for Nuclear and Particle Astrophysics on November 15, 1993, have been the principle and the goal behind *INPA*, an interdivisional center sponsored by the Nuclear Science and Physics Divisions at LBNL. Twenty years later, to the day, researchers gathered to celebrate the progress and discoveries made by the groups participating in INPA and peer into the future. The two-hour symposium included talks on the history of INPA, Instrumentation, Neutrino Astronomy, Neutrino Oscillations, Dark Matter, and Cosmology.

By all accounts the last twenty years have been both productive and exciting. Some of the highlights associated with *INPA* have been the Sudbury Neutrino Observatory's observation of oscillations in solar neutrinos and the verification of our basic understanding of how the sun shines; the discovery by the Supernova Cosmology Project of Dark Energy (2011 Nobel Prize in Physics); the measurement of fundamental neutrino oscillation parameters at KamLAND and at Daya Bay; the establishment of the first deep underground laboratory in the US at the Homestake mine; and the evidence for extremely energetic neutrinos of cosmic origin obtained with the IceCube detector at the South Pole, work that was featured on the cover of *Science* and declared by *Physics World* to be the Breakthrough of the Year.

Looking ahead, the observation of Dark Matter and neutrinoless double β decay (or the setting of limits that force new insights) are on the horizon and are being pursued in experiments with LUX and Majorana, respectively, at the Sanford Underground Research Facility in South Dakota.

Following the symposium, the attendees enjoyed a selection of goodies that recalled the legendary afternoon teas at *INPA* where NSD and PD staff rubbed elbows and talked physics.

One of six symposium speakers, NSD Senior Physicist Spencer Klein discusses neutrino astronomy with IceCube at the South Pole.

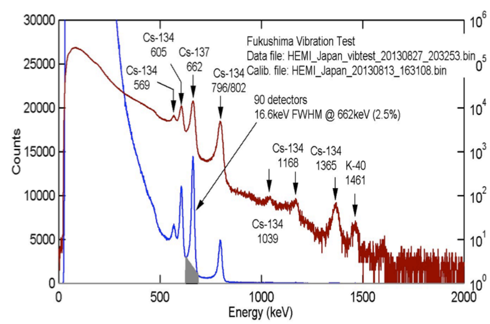
Symposium chairman Bob Stokstad, who served as the first INPA Director, introduces Saul Perlmutter for the closing talk, on Cosmology.

NSD scientists help to map radiation in Fukushima

The Fukushima Daichii Nuclear Power plant accident following the Great East Japan Earthquake in March 2011 released large amounts of radioactive materials that were dispersed locally and globally. High radiation levels were measured and residents were evacuated within 20 km of the plant. To ensure the speedy and safe return of the thousands of still evacuated people, areas with high radiation levels must be identified and cleared. Several efforts are underway led by the Japanese Atomic Energy Agency to map the radiation levels in large areas and to identify and localize areas of increased activity.

In order to more effectively detect areas of elevated radiation, scientists of the Applied Nuclear Physics program recently performed measurements to demonstrate advanced γ-ray imaging concepts employing the High-Efficiency Multimode Imager HEMI. This system consists of about 100 1-cm^3 CdZnTe semiconductor detectors arranged in a way that enables coded-aperture and Compton imaging modalities simultaneously with minimum weight and power in a very compact package. The development of HEMI was supported by the Domestic Nuclear Detection Office and collaboration with the Japanese Furukawa LLC enabled the modification of the system to fit onto the unmanned Yamaha RMAX helicopter currently being deployed in Japan. This system contains the HEMI array, a GPS/IMU unit, a video camera, the necessary computer and control boards as well as sufficient battery power to enable flights up to 30 minutes.

The HEMI is mounted under an unmanned helicopter and flown over the evacuated area.



One of the measured γ-ray spectra which are dominated by decays from ^{137}Cs and ^{134}Cs.

In August the system was shipped to Fukushima August and three flights were performed successfully. It operated very well on the helicopter even though it was never tested or originally designed to work on a helicopter. The spectral information confirmed the dominance of Cs isotopes in this area. The data analysis is still ongoing with the goal of developing better γ-ray image reconstruction schemes that can yield accurate maps of strong and widely distributed radioactivity (rather than merely imaging point sources in the lab). The plan is return to Fukushima in the near future to demonstrate the advantage of advanced γ-ray imaging concepts in more relevant areas in the evacuated zone to ultimately enable more effective means for identifying unsafe levels or radiation that need to be remediated in order enable reentry into the affected areas and thus allow people to return home.

NSD Fragments

Rod Clark takes over the reins

Recently, the LBNL Director, Paul Alivisatos made some changes to the labs' organizational structure, including the creation of the Physical Sciences area comprising the Divisions for accelerator and fusion research, engineering, nuclear science, and physics. It is being led by Associate Laboratory Director James Symons and to permit him to focus on this responsibility, Rod Clark was appointed as Acting Director of the Nuclear Science Division while the ongoing search for a new NSD Director is being concluded.

Rod received his B.Sc. and D.Phil. from the University of York in the United Kingdom. He is a Senior Physicist in the NSD and, for the past seven years, he has been co-leader of the Nuclear Structure Group at the 88-Inch Cyclotron. His research has been focused on the structure of exotic nuclei studied with modern techniques in particle and γ-ray spectroscopy.

Shortly after taking over the NSD reins, Rod celebrated his birthday in his new office.

Matthew Luzum and **Thorsten Kurth** have joined the Theory Program as postdocs. Matt obtained his Ph.D. at the University of Washington in Seattle and thereafter spent three years at Saclay near Paris, while Thorsten graduated recently from the University of Wuppertal in Germany.

An **EMMI Workshop** on *Heavy Flavor and QCD Phase Structure in High-Energy Collisions* was held at LBNL November 20-22, organized by V. Koch, H.G. Ritter, and N. Xu of LBNL and H. Oechhler from Heidelberg. The key topics were the phase structure of QCD, heavy flavor production, partonic energy loss, collective motion, and lattice results. EMMI, the ExtreMe Matter Institute of which the NSD is an international partner, was founded at GSI in Germany in 2008 within the framework of the Helmholtz Association. The workshop was well attended and it provided a stimulating atmosphere for vigorous science discussions. A total of 31 formal presentations were made by leading researchers drawn from around the world.

The NSD Newsletter is edited by Jørgen Randrup (JRandrup@LBL.gov) and issues are archived on the NSD home page: https://commons.lbl.gov/display/NSD/home/.